

The Status of Bioreactors



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Bioreactor Defined



“.....a sanitary landfill operated for the purpose of transforming and stabilizing the readily and moderately decomposable organic waste constituents within five to ten years following closure by purposeful control to enhance microbiological processes. The bioreactor landfill significantly increases the extent of waste decomposition, conversion rates and process effectiveness over what would otherwise occur within the landfill.”

Why Operate a Landfill as a Bioreactor?



- to increase potential for waste to energy conversion,
- to store and/or treat leachate,
- to recover air space, and
- to ensure sustainability

Status



- 1993 - less than 20 landfills recirculating leachate
- 1997 - ~ 130 landfills recirculating leachate
- My estimate - ~ 5% of landfills

Regulatory Status



- EPA permits recirculation of indigenous liquids into landfills with Subtitle D liners
- Some states more stringent
- EPA is considering nonindigenous liquid addition

EPA Concerns



- long-term fate of metals,
- the lack of data that demonstrate the reduction of environmental risk and liability, and
- increased operational requirements
- landfill gas capture,
- leachate treatment and storage,

EPA Concerns- Cont'd

- landfill space and capacity reuse,
- greenhouse gas abatement,
- bioreactor design,
- solid waste density considerations,
- settlement,
- waste pretreatment,
- cover,
- management of amendments.

Europe



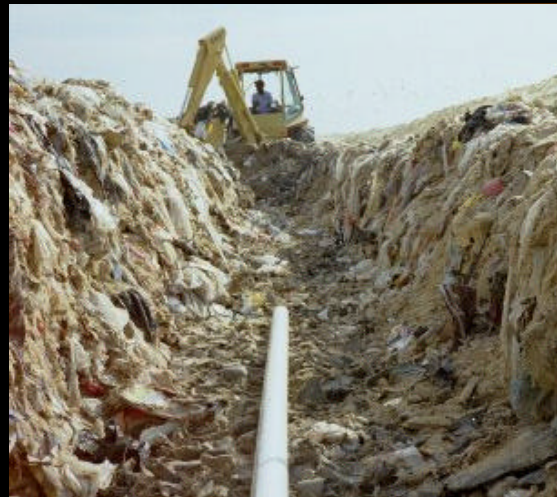
The European Union Council Directive on Landfilling of Waste has identified the need to optimize final waste disposal methods and ensure uniform high standards of landfill operation and regulation throughout the European Union (EU).

Essential Needs for a Bioreactor

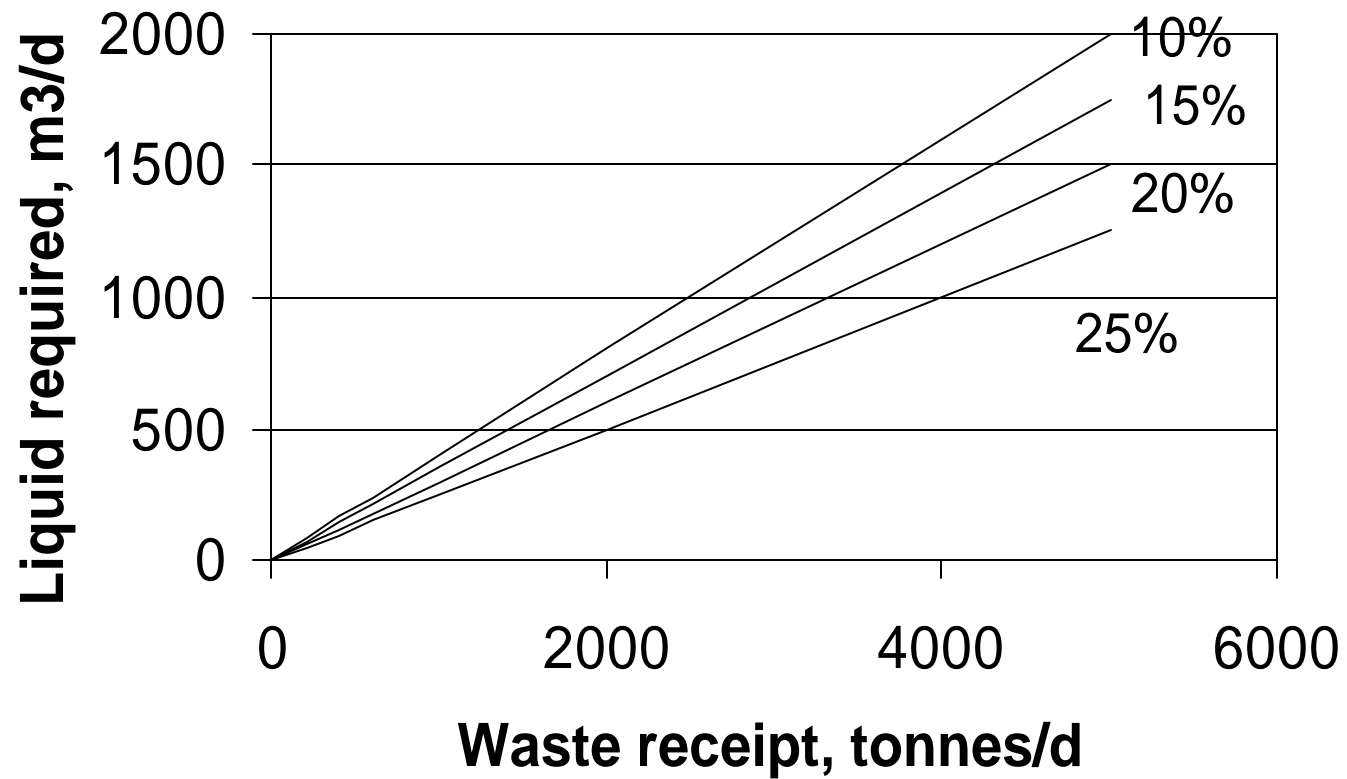


- Composite liner
- Appropriate density of MSW
- Appropriate daily cover
- Leachate recirculation system
- Active gas collection system
- Appropriate final cover system
- Competent landfill operator

Leachate Recirculation



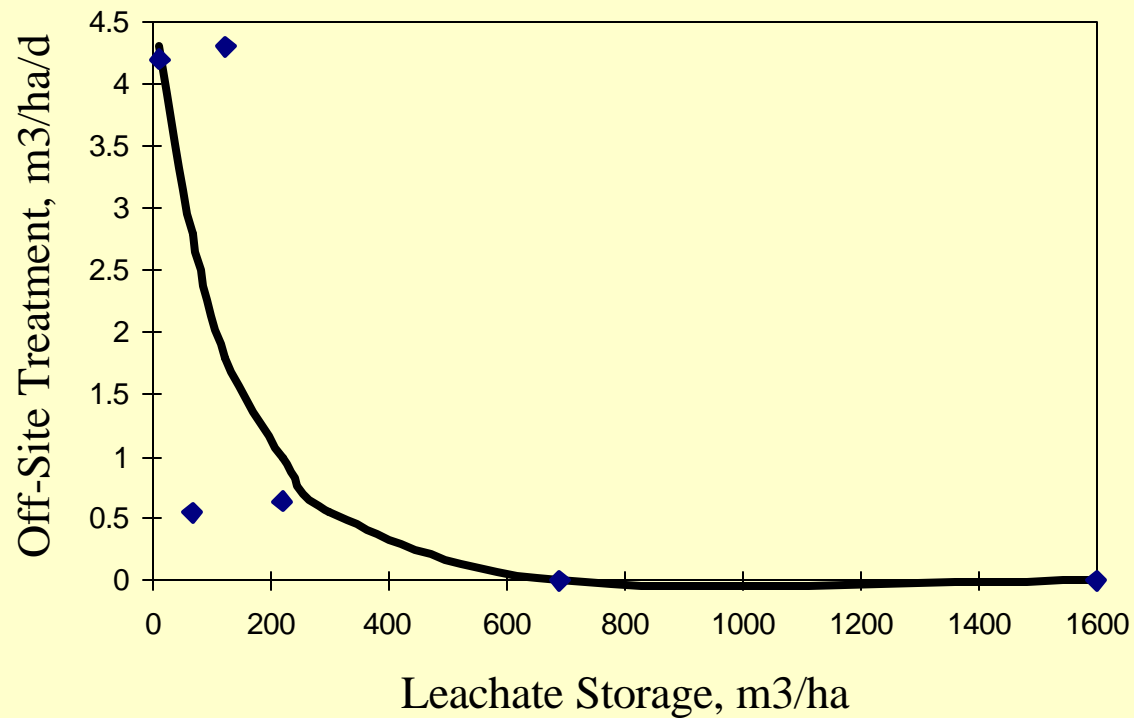
Leachate Quantity



Storage



Leachate Storage Impact on Off-site Treatment



Leachate Collection System Performance



Clogging Potential



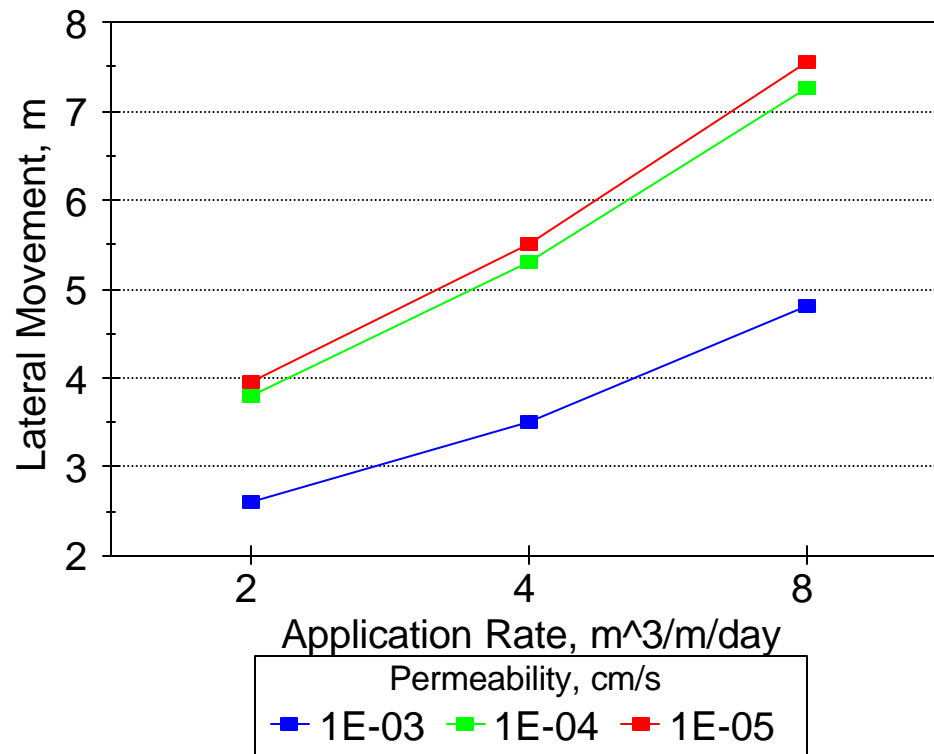
Performance Monitoring



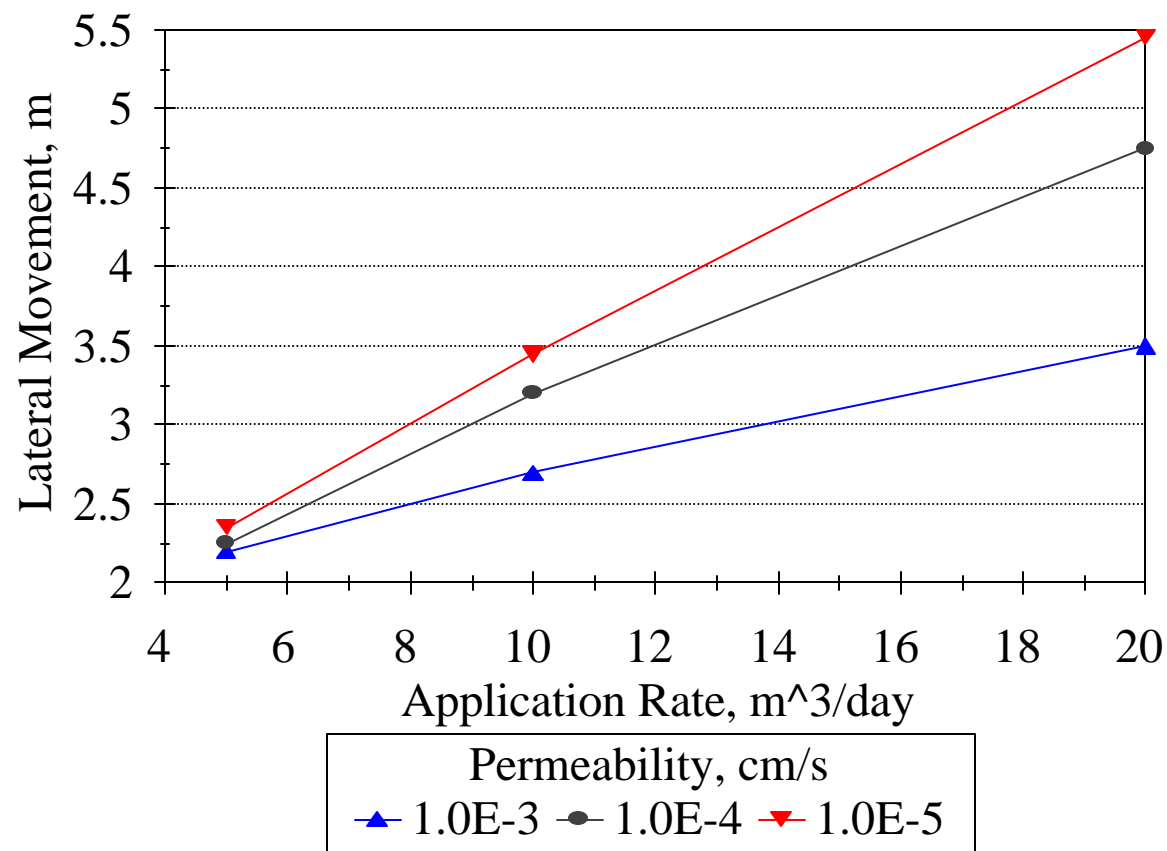
Maintenance



Bioreactor Design - Horizontal Device Placement



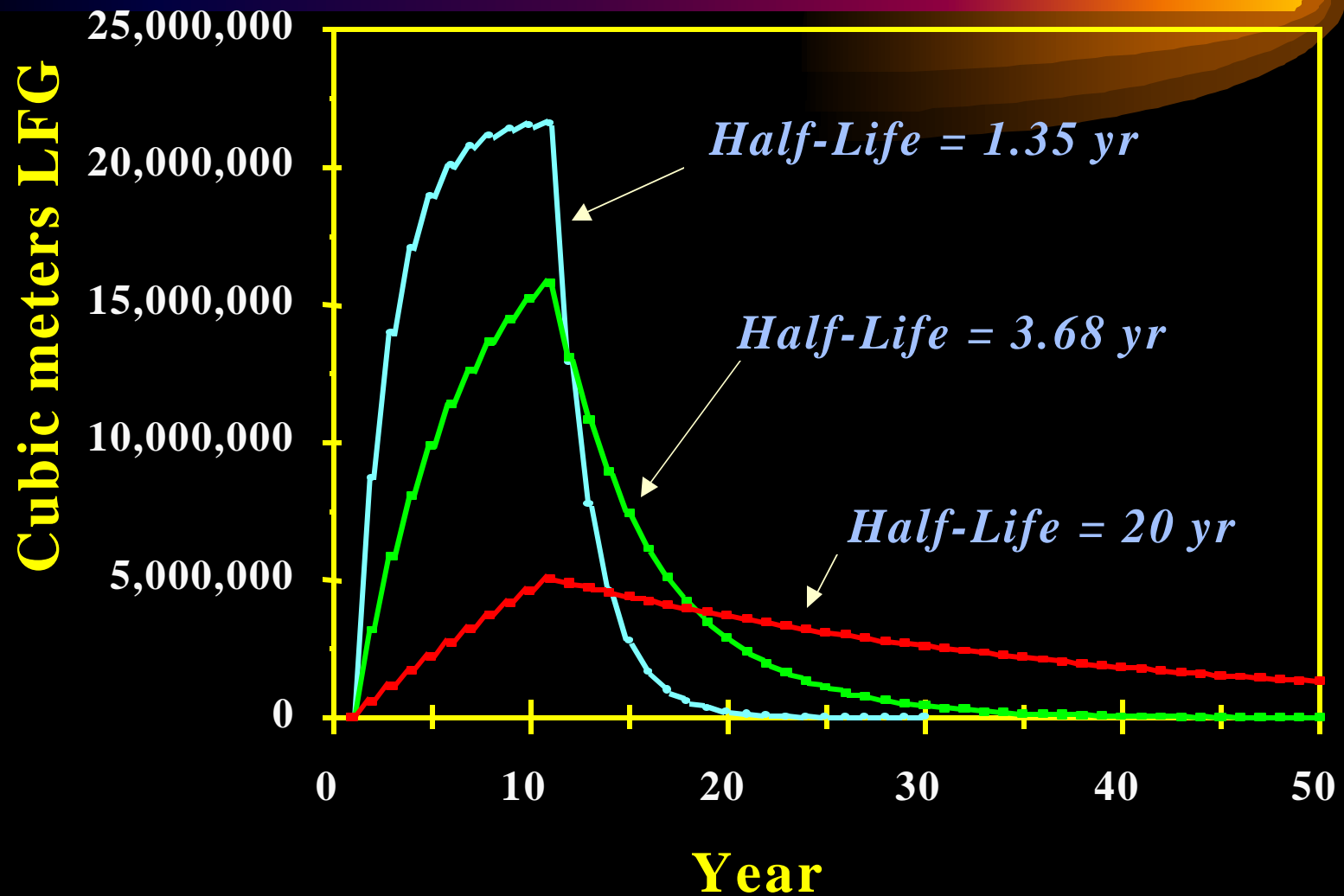
Bioreactor Design - Vertical Well Placement



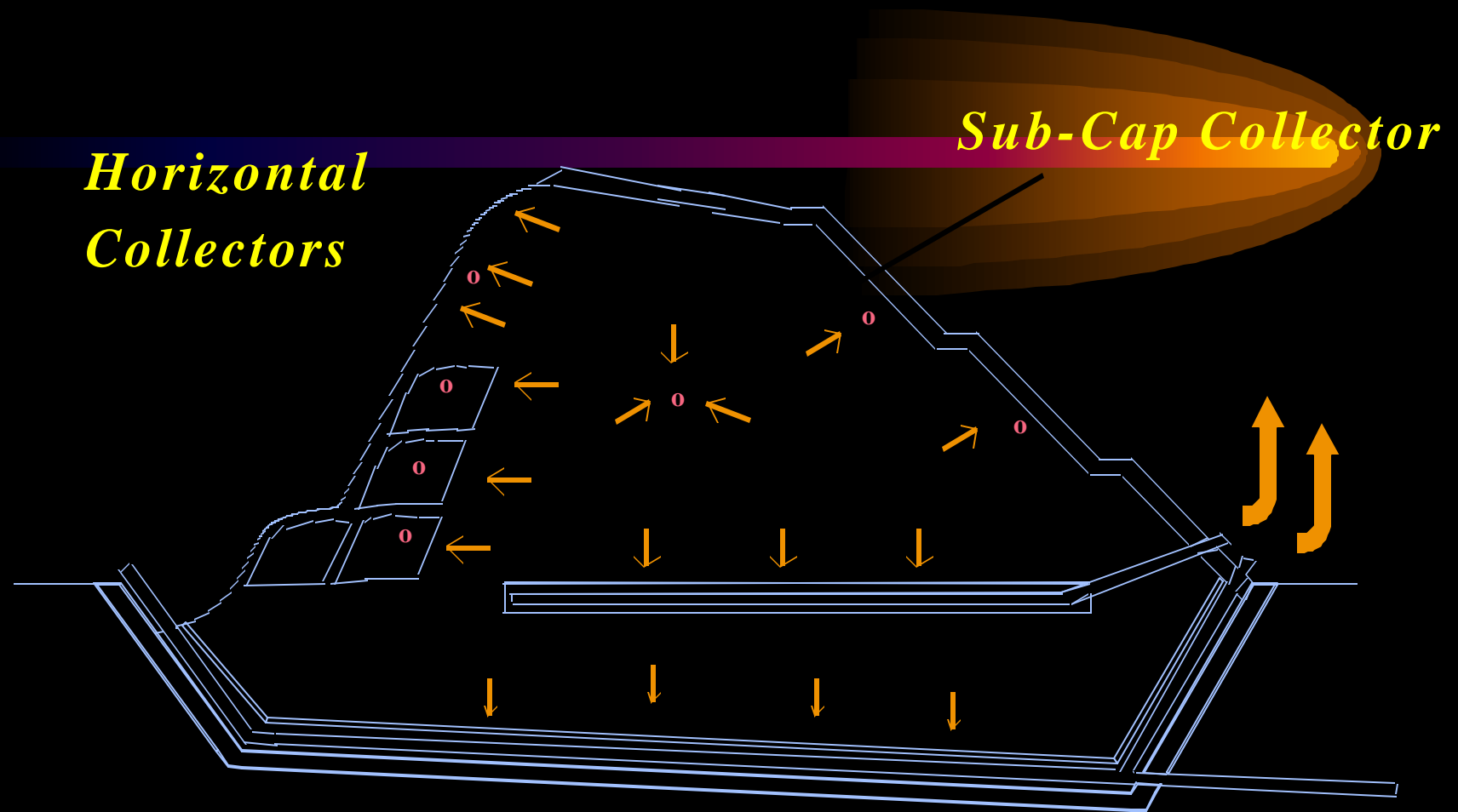
Gas Collection



LFG Generation Curves



LFG Collection From Operating Landfills



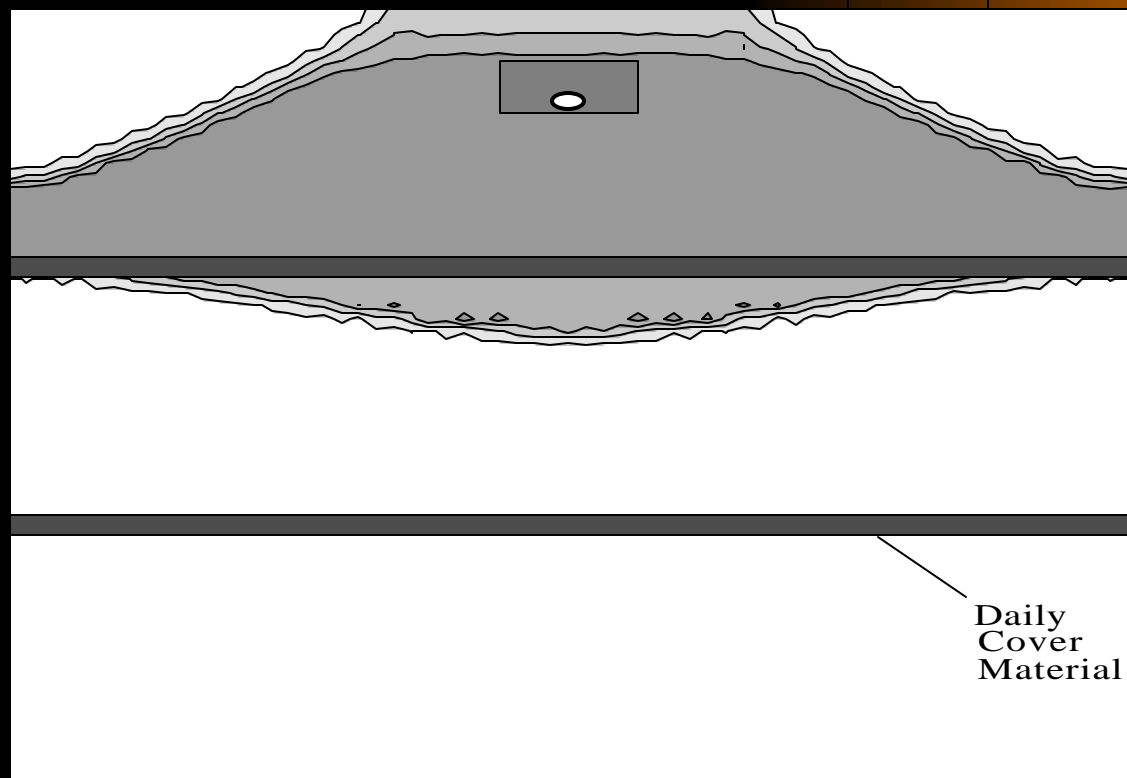
Leachate Collection System - LFG Collector Network

Odor Potential





Cover Issues



Leachate Outbreaks



Alternative Daily Cover



Impact on landfill Operations



Impact on landfill Operations



- Construction (sequencing)
- Location of roads/access
- Monitoring
 - Settlement
 - Side Seeps
 - Odors

Research Needs



Long Term Sustainability

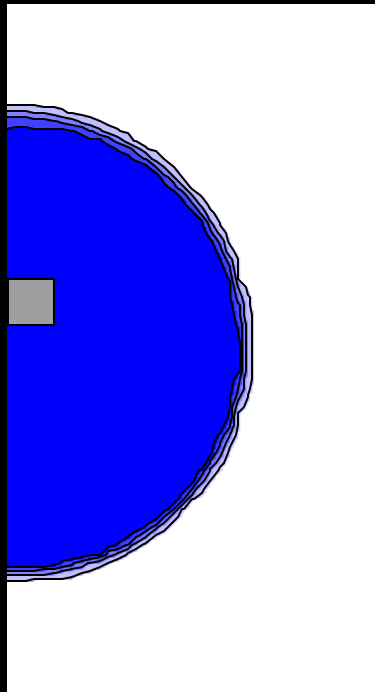


- Fate of metals
- Fate of other inorganics/recalcitrants
- Flushing bioreactor?

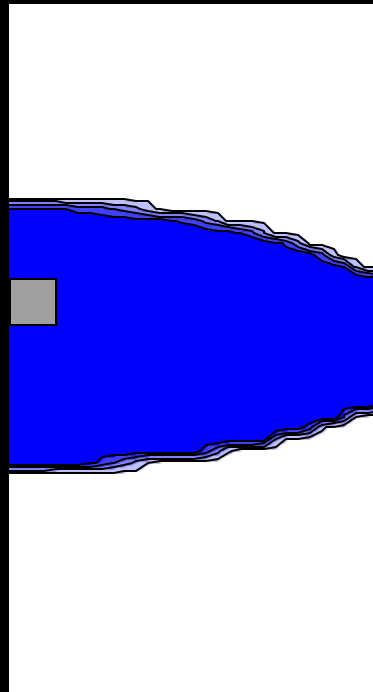
Waste Compaction



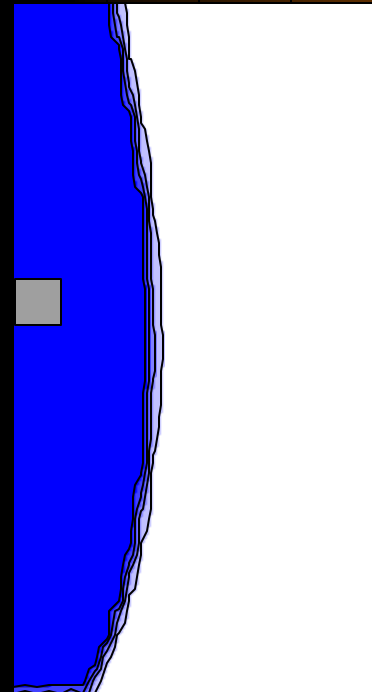
Vertical Permeability = 10^{-4} cm/s



$$K_V = K_H$$



$$K_V < K_H$$



$$K_V > K_H$$



Settlement



- The Keele Valley Landfill - settlement rates of 10-12 cm/month in wet areas, 5-7 cm/month in dry areas.
- Yolo County, CA test cells - wet cell settlement rates > three times parallel control cell (17 mos)
- lower settlement enhancement (~ 5%) was reported at aerobic cells in Columbia Co
- The Trail Road Landfill in Ontario, Canada reported a 40% recovery of airspace (8 yrs)

Nonindigenous Liquids

- Supplement nutrients and moisture,
- Dispose of liquid waste products,
- Compensate for insufficient leachate volumes, and/or
- Avoid concentration of inorganic contaminants in leachate

Waste

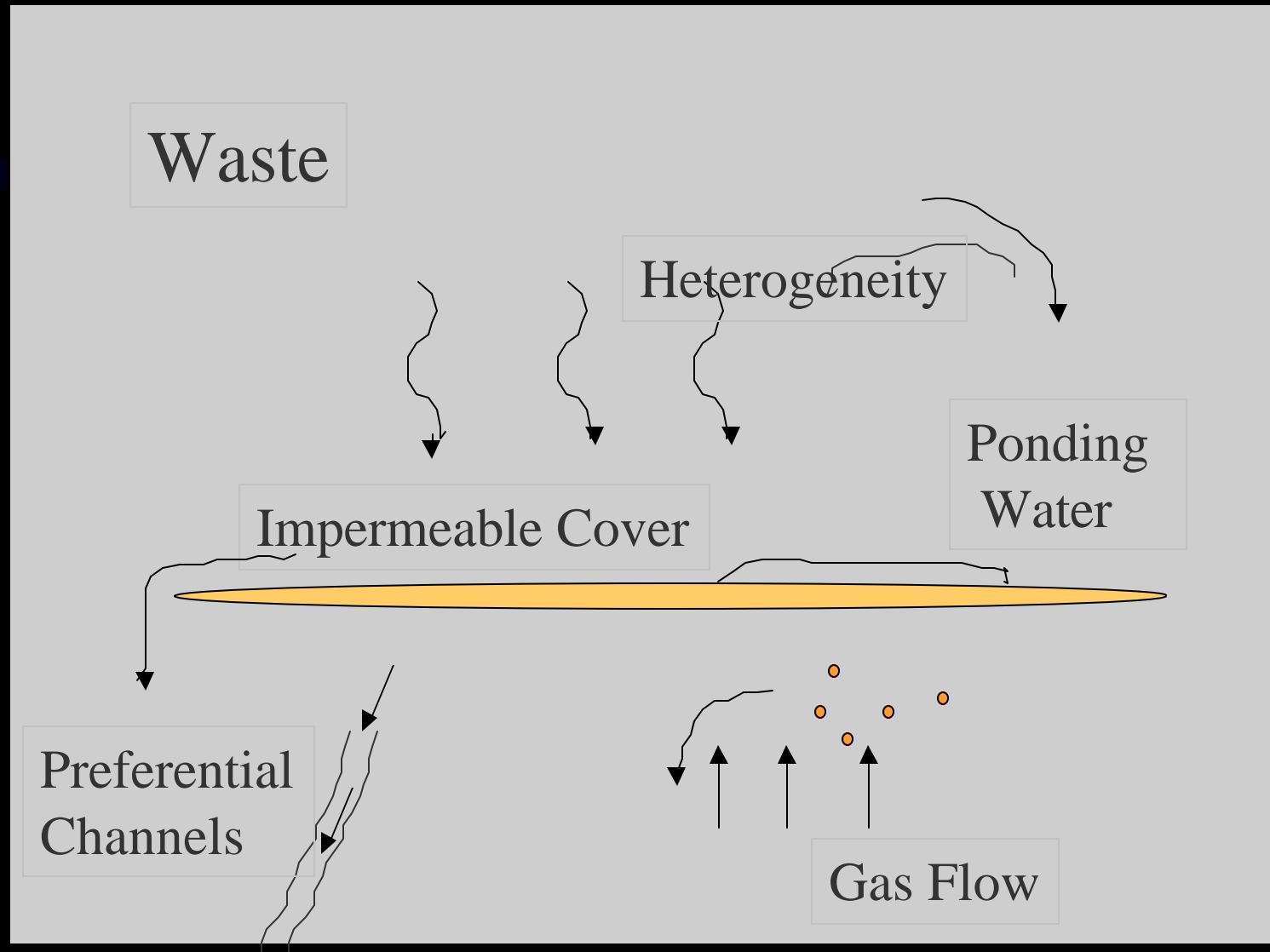
Heterogeneity

Ponding
Water

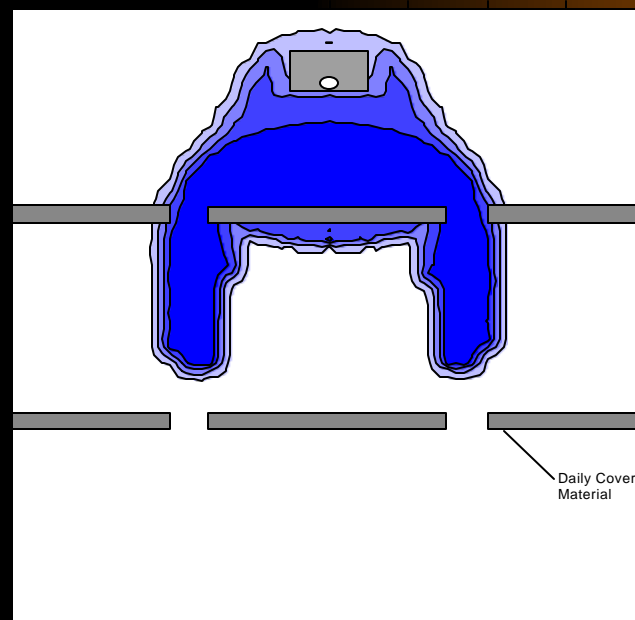
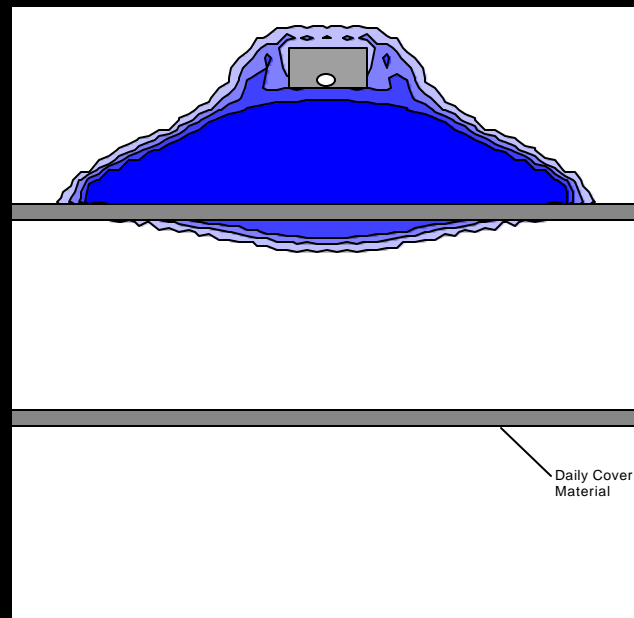
Impermeable Cover

Preferential
Channels

Gas Flow



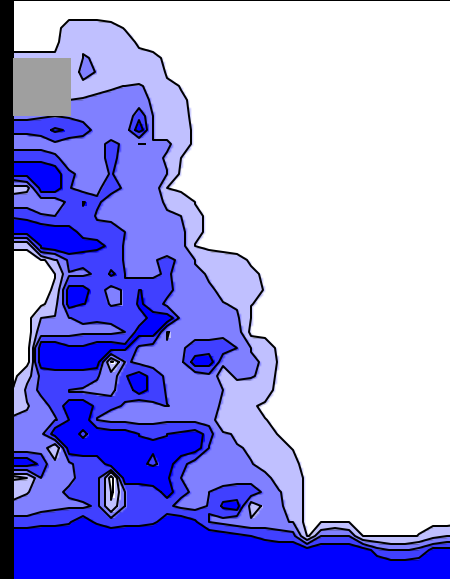
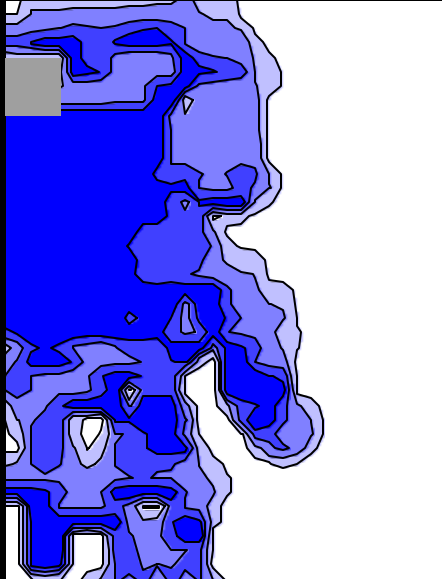
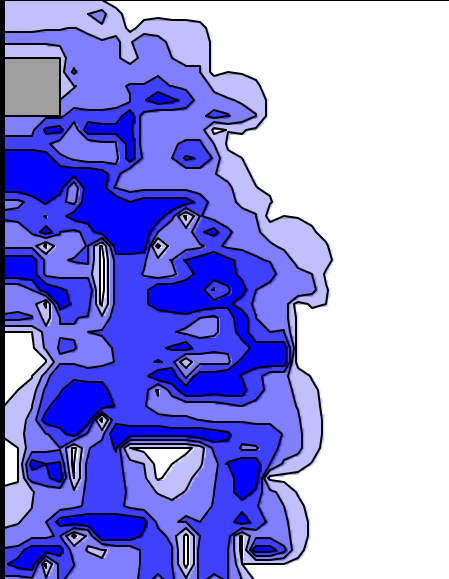
Leachate Applied Intermittently at an average rate of $2 \text{ m}^3/\text{m}/\text{day}$



Waste Permeability = 10^{-3} cm/s

Daily Cover Permeability = 10^{-5} cm/s

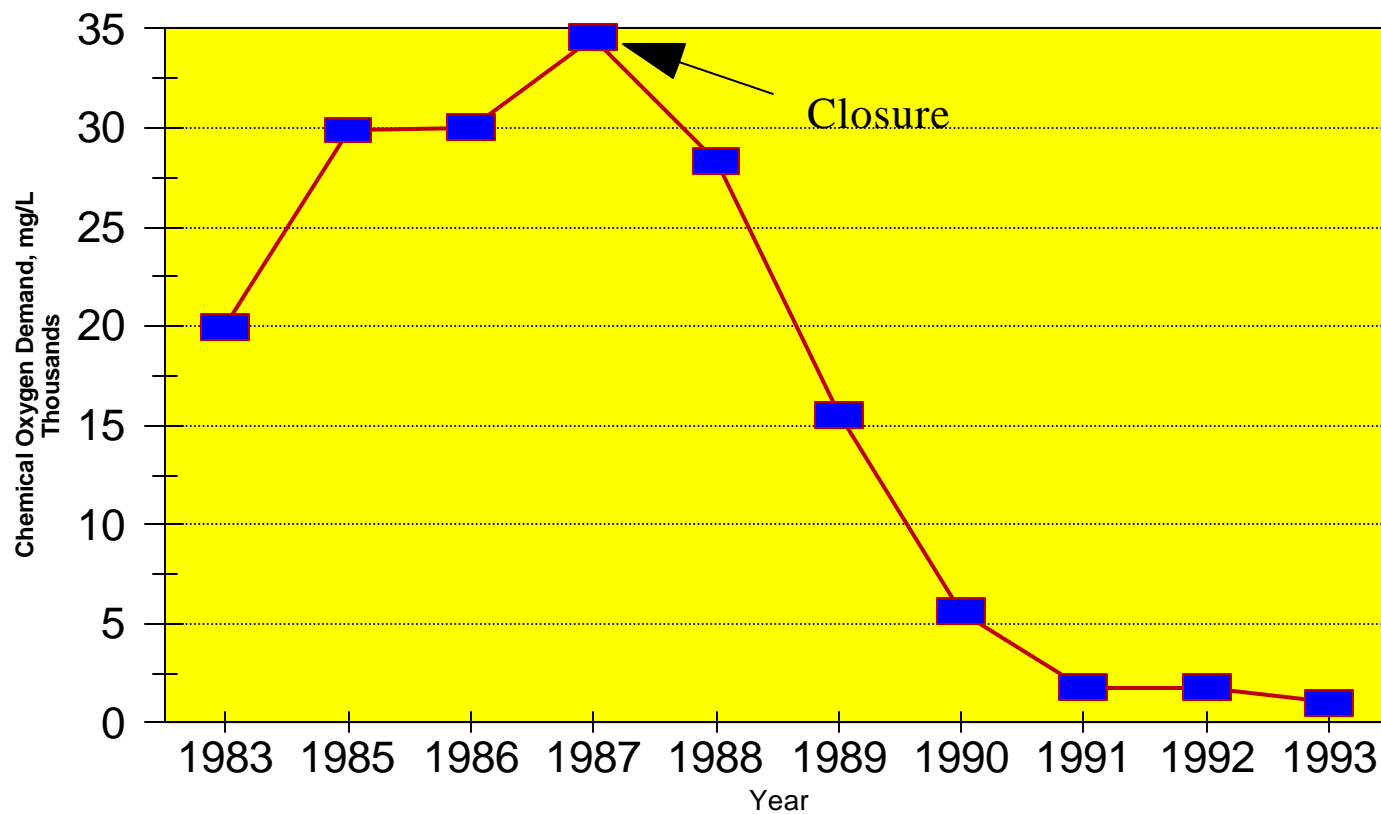
Heterogeneities



Landfill Stability



Leachate Quality



Impact of Waste Processing



Recovery of Composted Materials



Aerobic Bioreactor



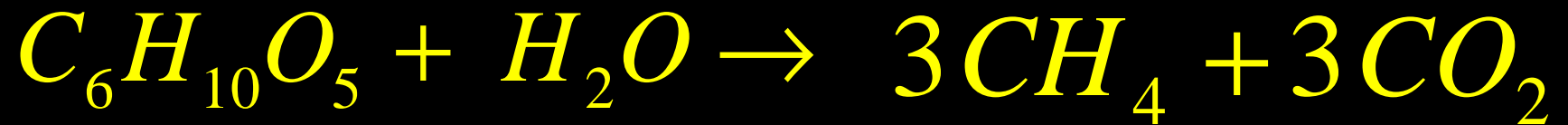
- Rapid stabilization of waste
- Enhanced settlement
- Evaporation of moisture
- Degradation of organics which are recalcitrant under anaerobic conditions
- Reduction of methane emissions

Research Issues - Aerobic Bioreactor

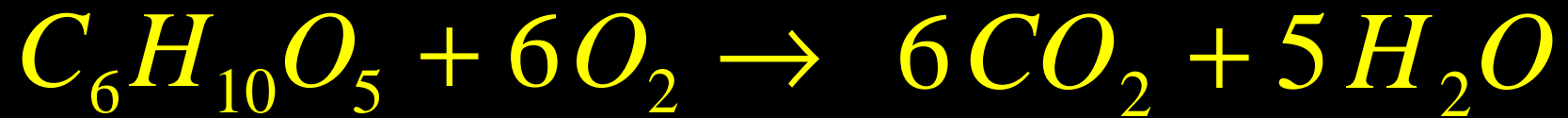


- How much air is needed?
- How can air be delivered?
- What is the impact on the water balance?
- How are landfill fires prevented?
- What are the economic implications?

Anaerobic Decomposition

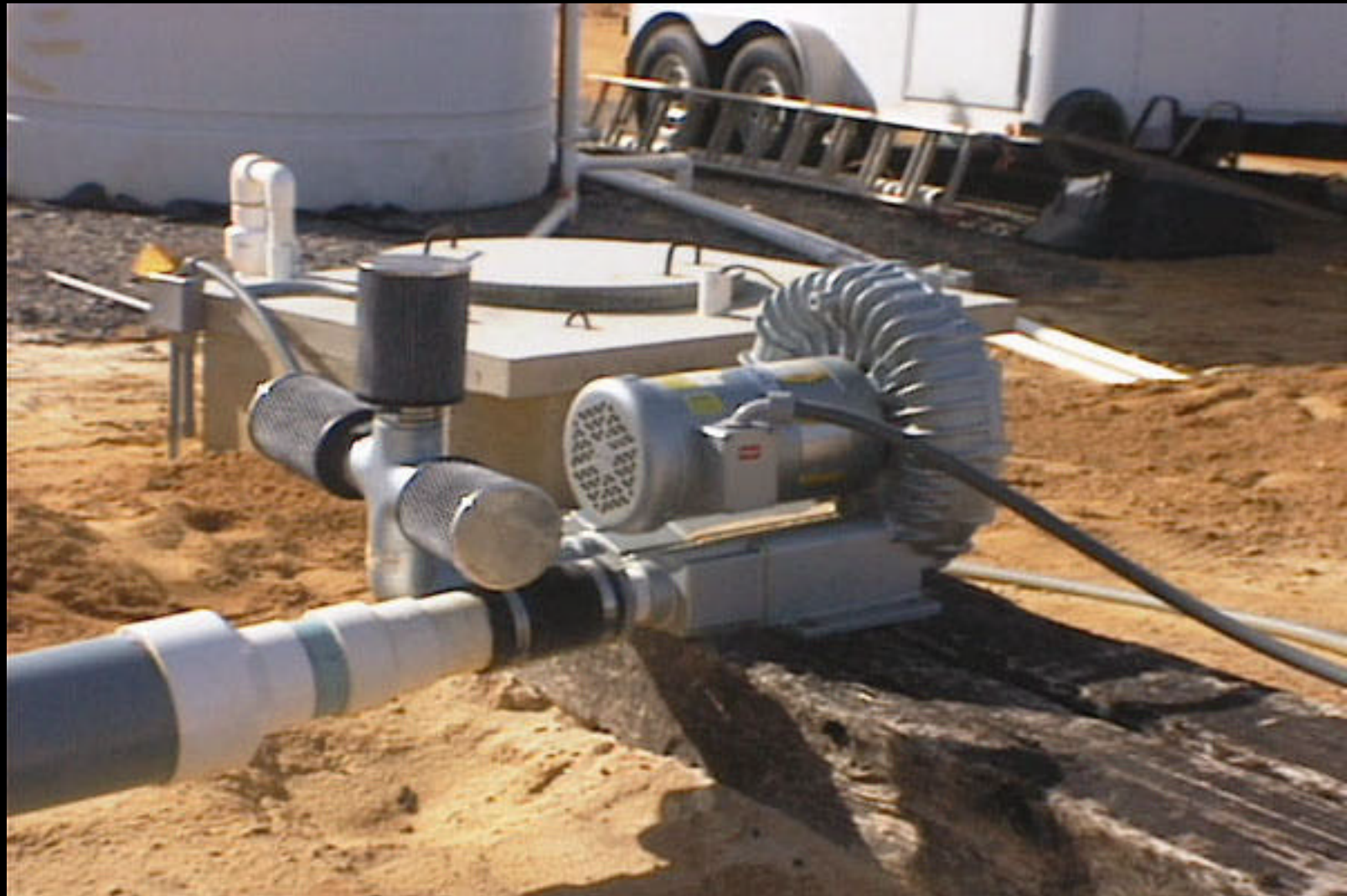


Aerobic Decomposition



Aerobic Landfill







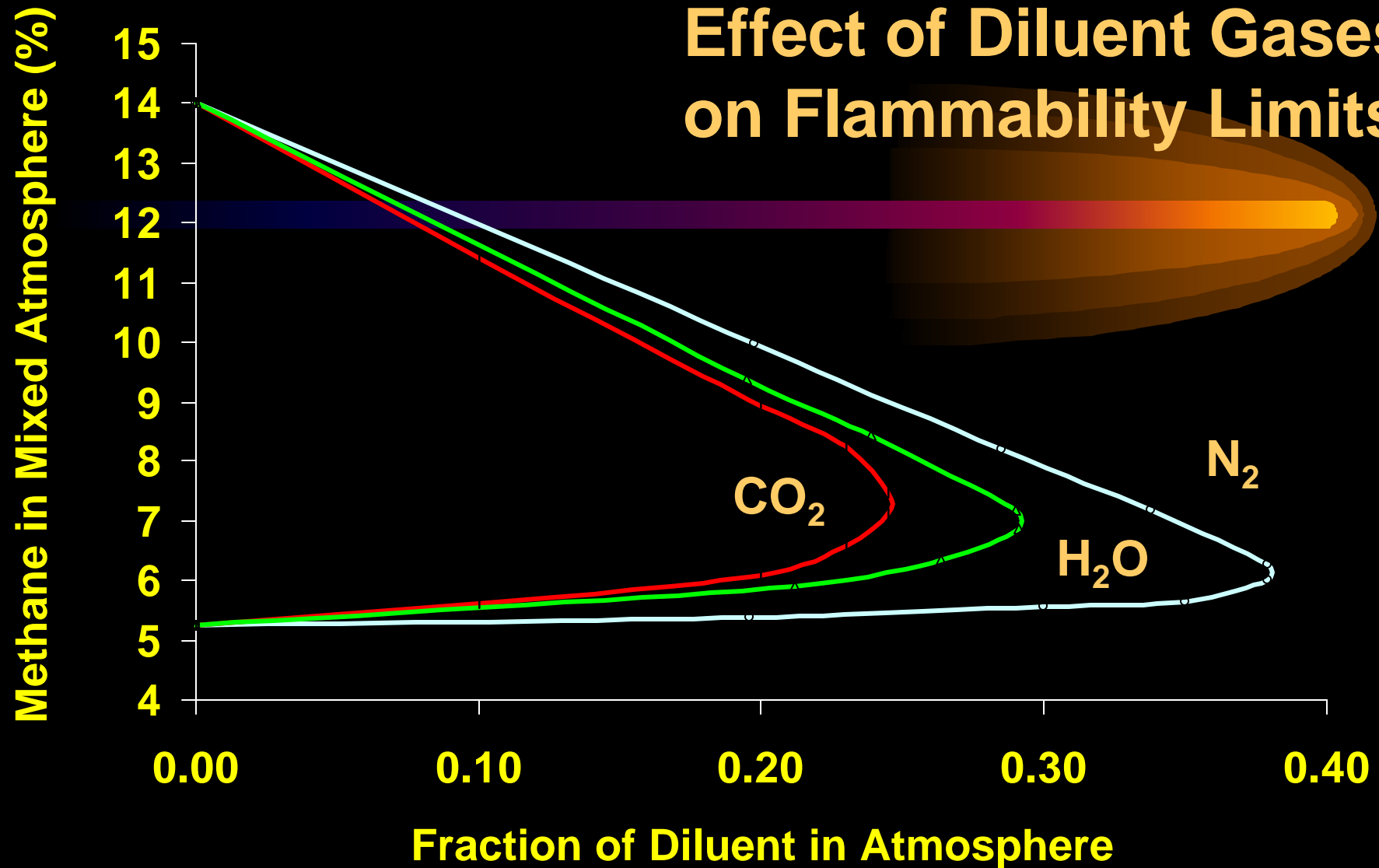
Flammability of Landfill Gas



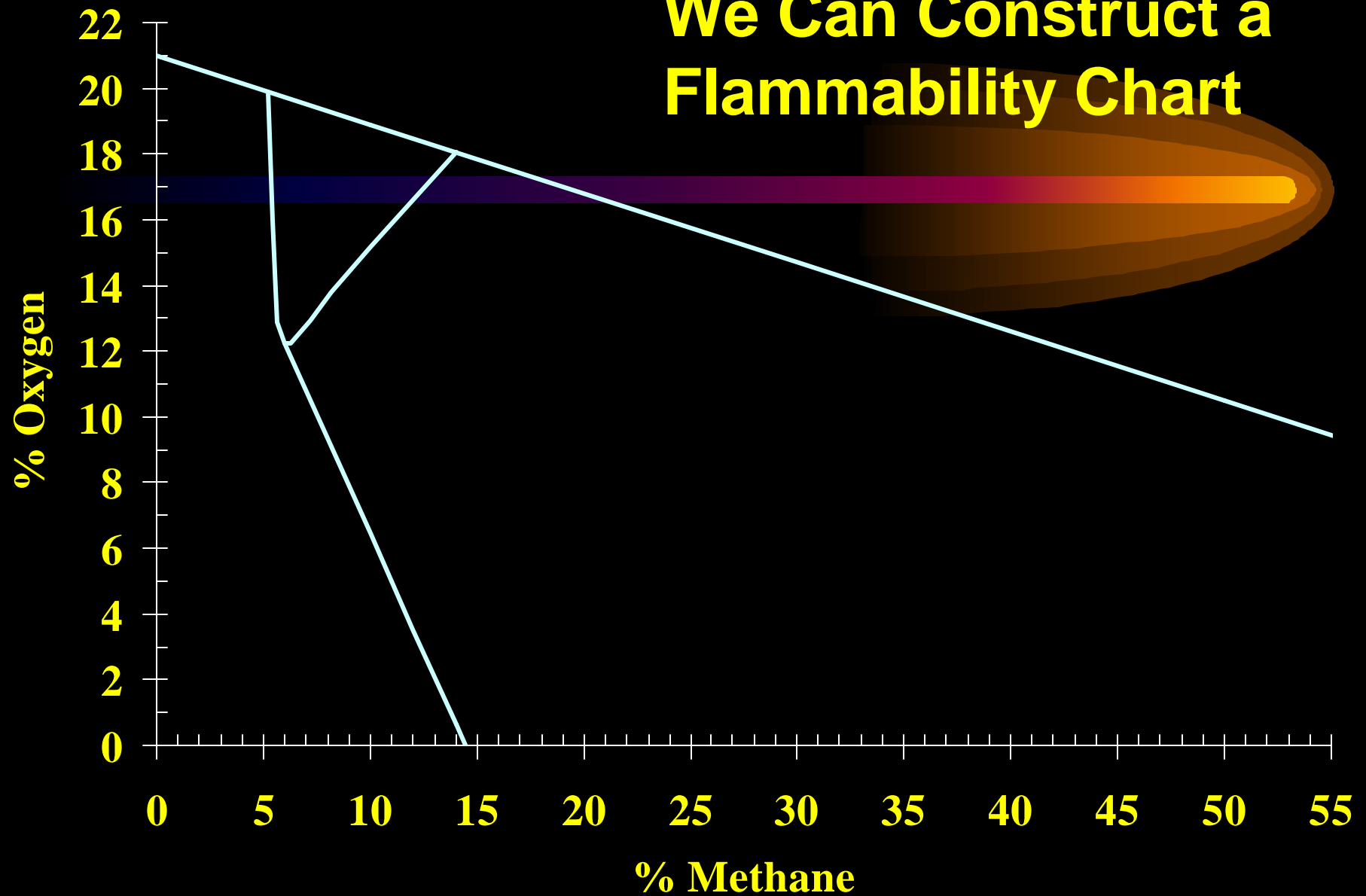
Explosive Range of Methane in Air

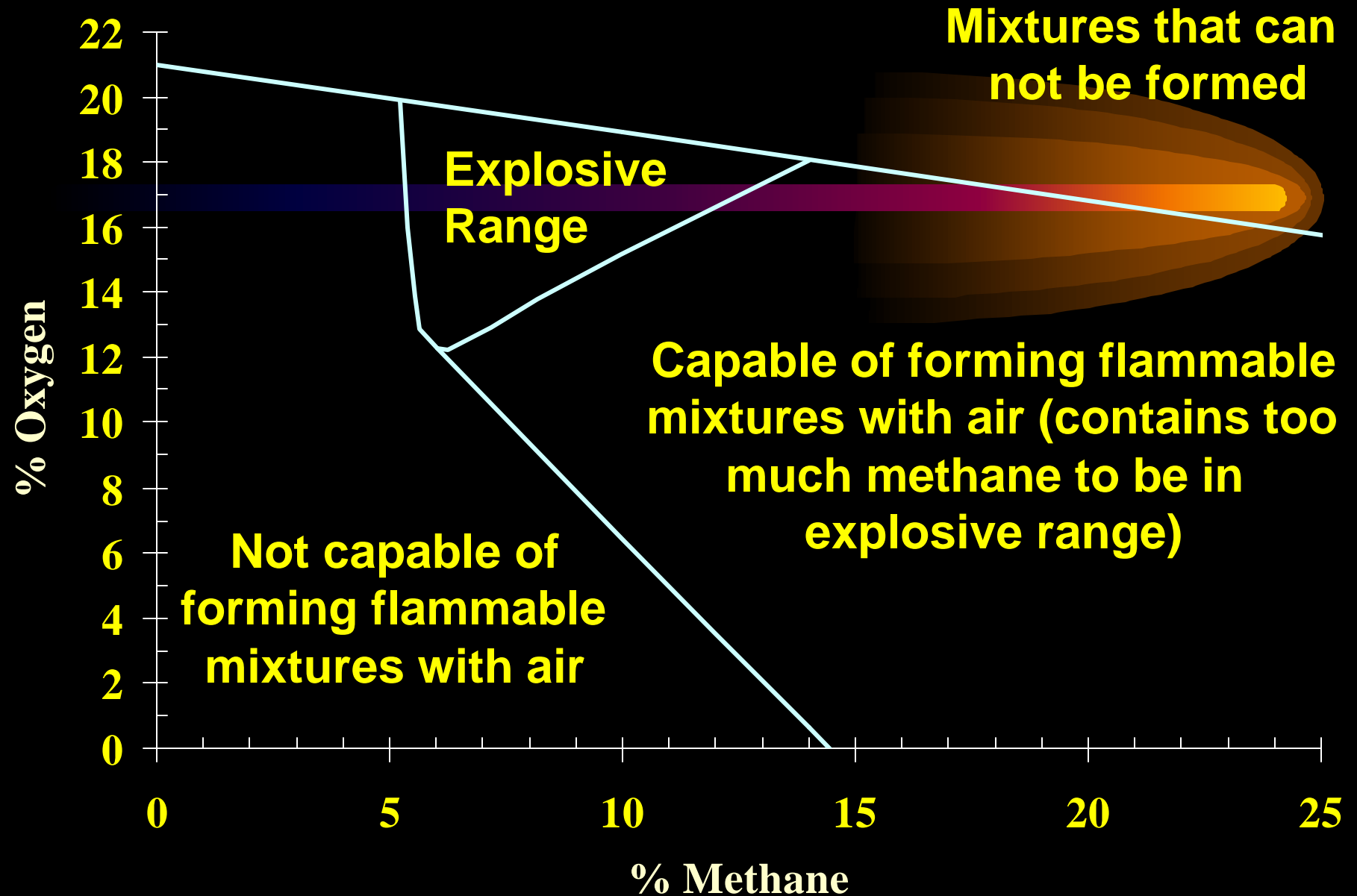
5% to 14/15%

Effect of Diluent Gases on Flammability Limits



We Can Construct a Flammability Chart





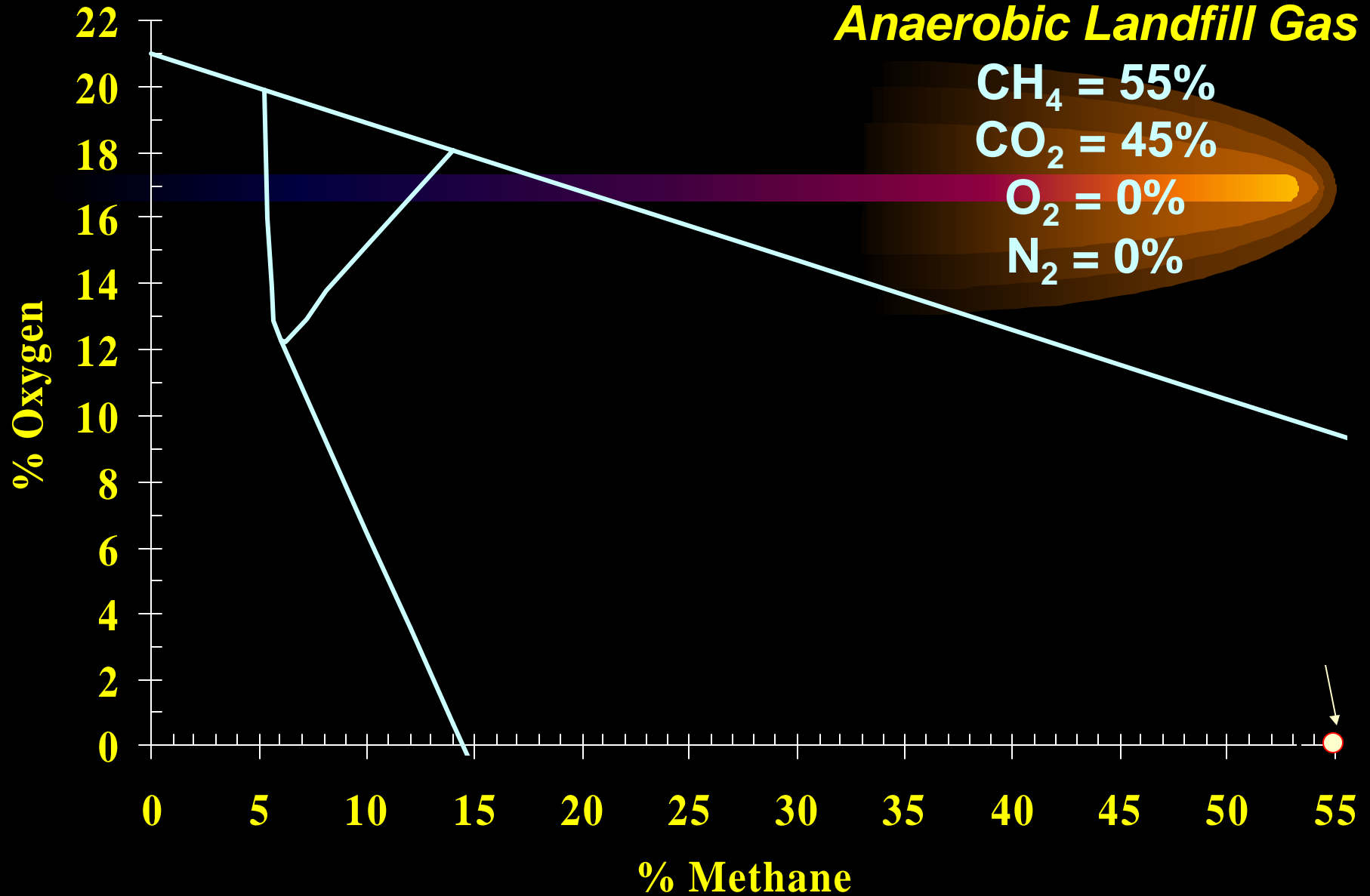
Example:
Anaerobic Landfill Gas

$\text{CH}_4 = 55\%$

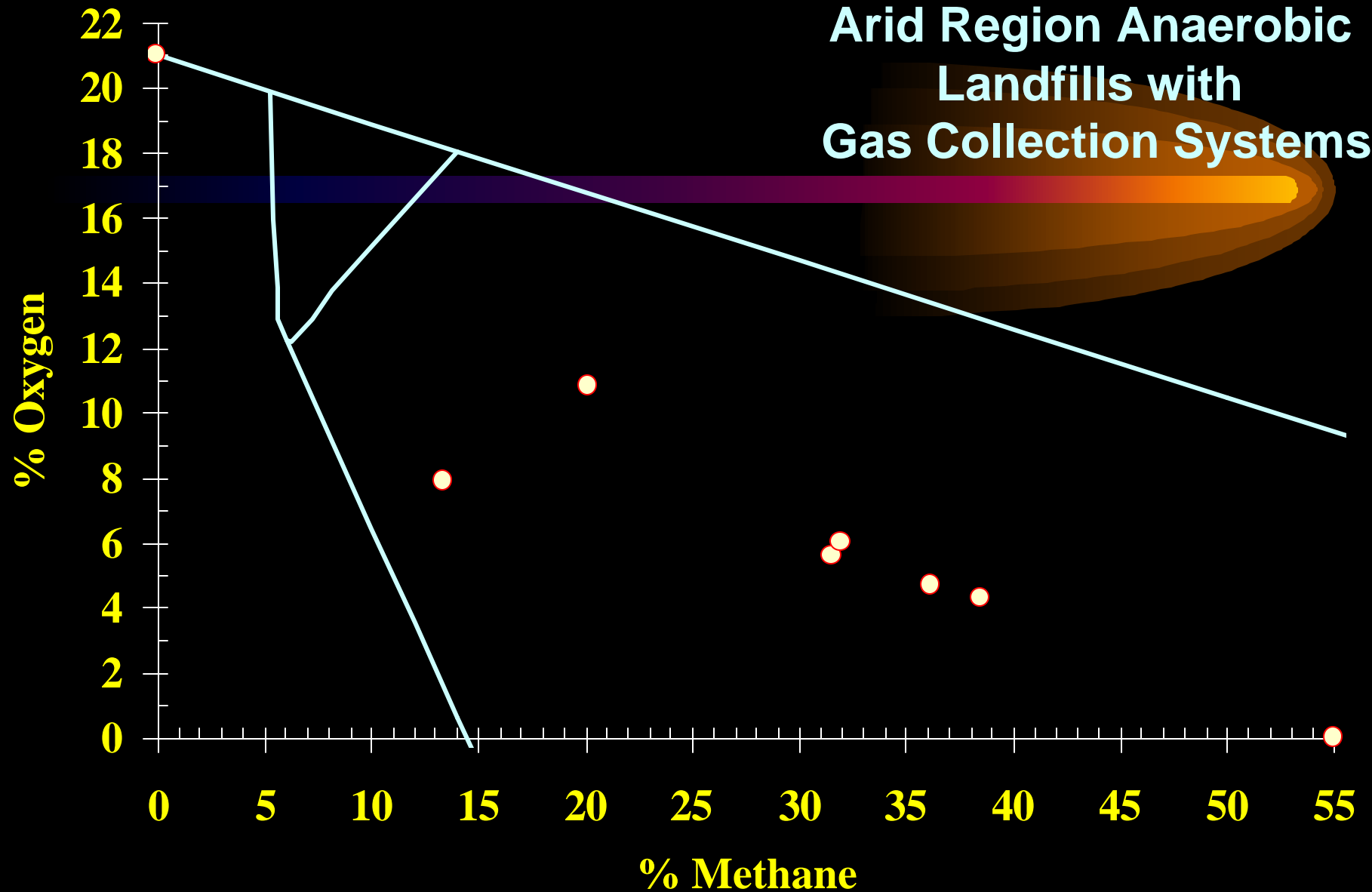
$\text{CO}_2 = 45\%$

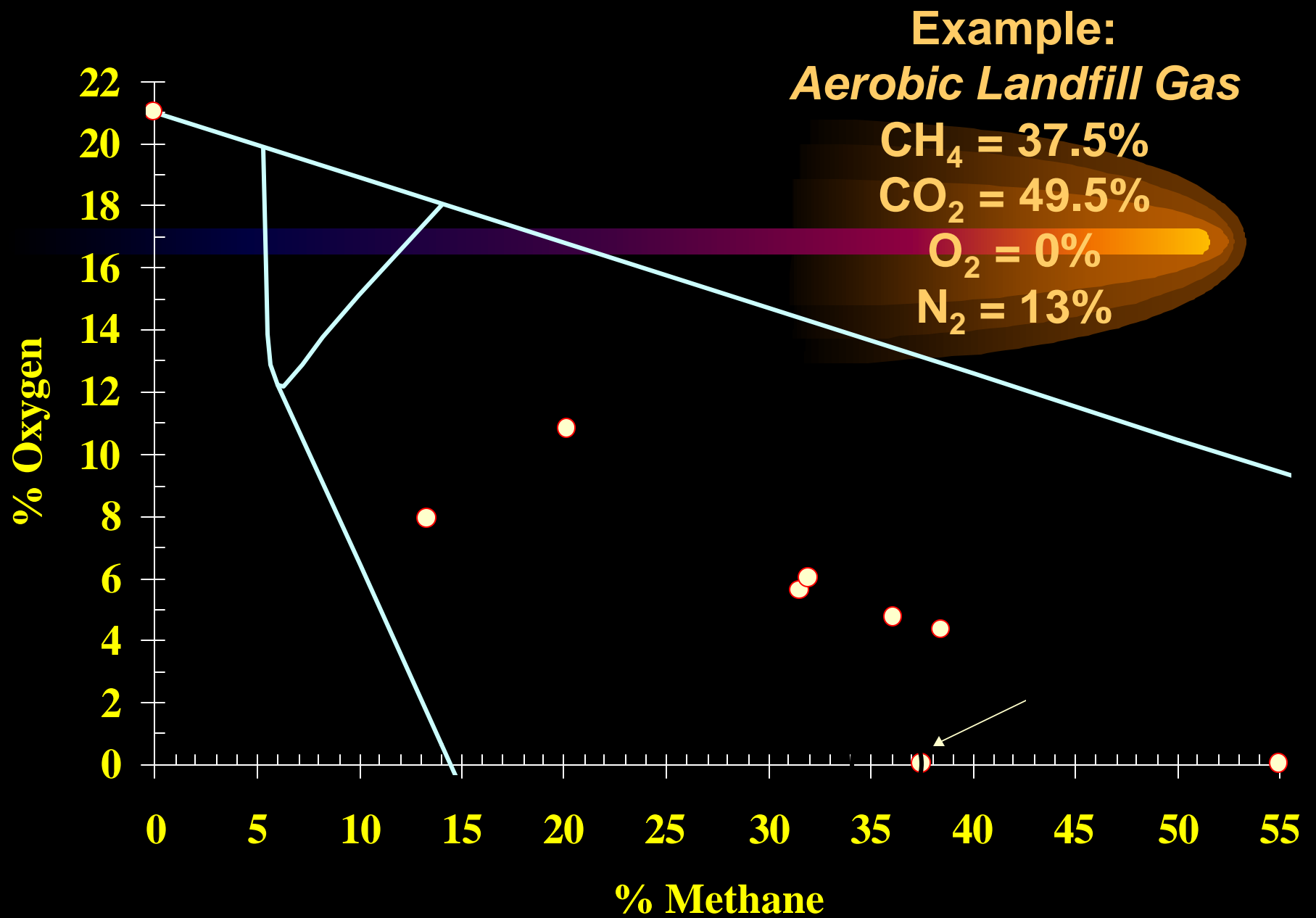
$\text{O}_2 = 0\%$

$\text{N}_2 = 0\%$

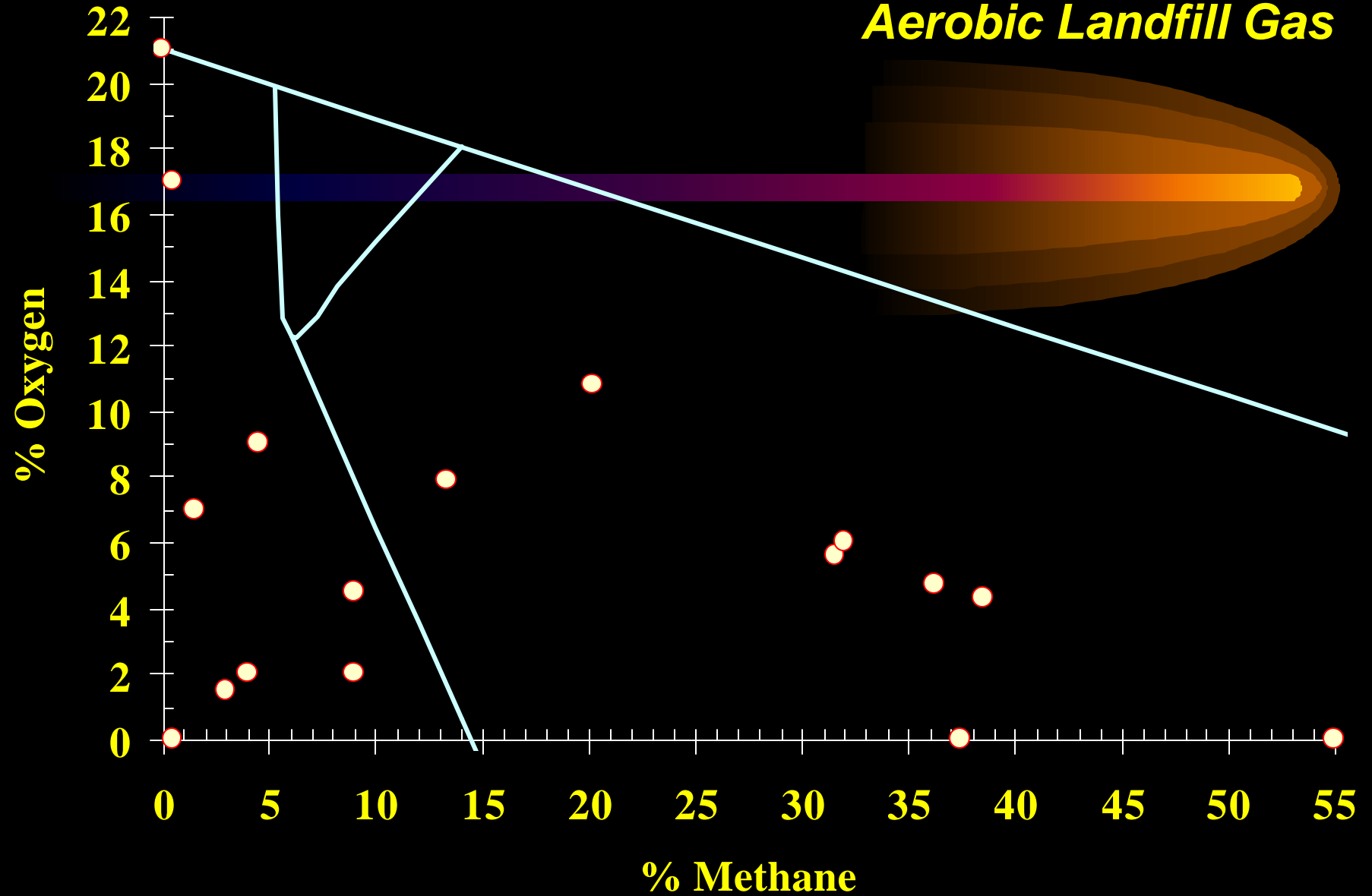


Example:
Arid Region Anaerobic
Landfills with
Gas Collection Systems





**Example:
Aerobic Landfill Gas**



Economic Impacts



Benefits

- Enhanced gas production
- Recovered space
- Reduced env. impact
- Reduced post-closure care

Costs

- Capital costs
- Operating costs

